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AUTOMAKER'S SUPPLY CHAIN FRAGILITY: CASE STUDY OF GLOBAL CRASH OF PA-12

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***Abstract**. The stop of production in an automaker due to lack of parts is highly undesirable and its financial impacts are huge. Many reasons may contribute to parts shortage in assembly line, such as: fails in the production schedule of the automobile industry or its suppliers, delays in transport just-in-time, reception of defective parts lots, strikes, etc. Anticipating a potential failure to provide with sufficient time to act, it is desirable?No doubt, because it would allow in most cases the creation of a logistic action plan in order to eliminate or to minimize its possible impacts. However, when the situation is the rupture by lack of productive capacity of a specific raw material used by almost all automakers around the world, which has been the case with PA-12 in first years of this decade, actions must go beyond of logistic solutions. This kind of situation implies engineering strategies to develop and validate technical solutions of alternative materials in a very restricted time. PA-12 is used in several parts, such as fuel systems (pipes and tank) and brake, clutch or blow-by pipes, for example.This article goal is to present, through a case study in an automaker, the strategies adopted by the engineering team to replace the use of raw material PA-12 wherever it was possible to ensure its using when it was strictly necessary.*

***Keywords**: Automotive Industry, PA-12 crisis, raw material, supply chain*

1. INTRODUCTION

Considering the focus on environmental conservation, there's an increasing pressure on automakers for lower consumption vehicles. Studies show that 10% mass reduction, no other factors changing, may improve 6 to 7% reduction in fuel consumption. One of the project philosophies applied in this direction was based in lightweight materials, such as aluminum and plastics (Furtado and Pereira, 2007).

According to Medina (2002), "plastics use has grown fast in the beginning of 70's, in the first try to make lighter cars to reduce fuel consumption, face to petroleum crises from 1973 and 1976. Then, a decade of fast advances has started, first in vehicle interior and body, replacing wood and some metals, following to new electronic components, in 80's. In 15 years plastics doubled their participation in vehicle total weight." This evolution can be saw in Fig. 1.

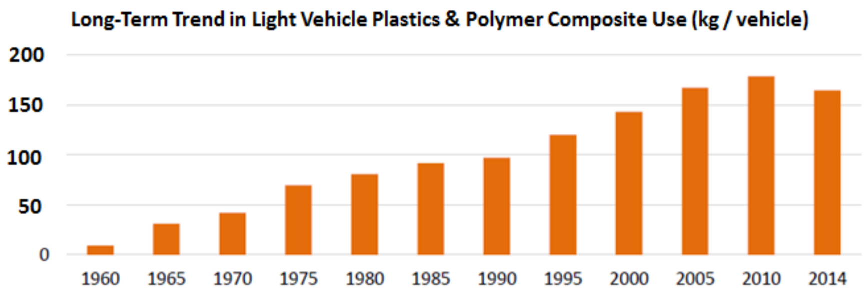

Figure 1. Vehicle plastics and polymer composite use since 1960 in United States. Source: Adapted from American Chemistry Council, 2015.

Among all of polymers, polyamide 12 (PA-12), so called nylon-12, was prized by automakers and other industries for their chemical resistance, abrasion resistance, fatigue resistance, to be used in plastic fuel lines and brake lines. (Sheffi, 2015).

But this growing also brought dependence of these materials to automotive industry and its consequences have become evidents in 2012: an accident occurred on March 31st, exposed the fragility of the global supply chain of the automotive sector. A fire destroyed the plant of Evonik in Marl, Germany. About a quarter of PA-12's world supply was cuted off after this incident. (Automotive Business, 2012). Any substitute plastic would have to go through rigorous testing to make sure it would work for a specific automotive part. Those tests could take months.

This paper describes the strategies and the action plan applied by an automaker placed in souther Rio de Janeiro to face this shortage of raw material. It's organized as follows: section 2 describes the PA-12 uses in automotive industry. 3rd section presents the crisis of PA-12 at 2012. Next section, 4th,shows the case study of a brazilian automaker's. Section 5 brings analyses, followed by conclusions and lessons learned in 6th section.

2. THE APPLICATIONS OF PA-12 IN THE AUTOMOTIVE INDUSTRY

Nowadays, engineering plastics are also widely used in mechanical applications. Among them, for cases where there is contact with corrosive fluids, such as fuel, stand out the polyamides (PA). They're almost always present in the components of fuel lines: such as pipes, cold start system and pumps. This diversified application makes them very important materials on almost all points of automotive fuel systems all around the world (Automotive Business, 2012). Fuel system tipical components of a B-segment car are shown in Fig. 2.

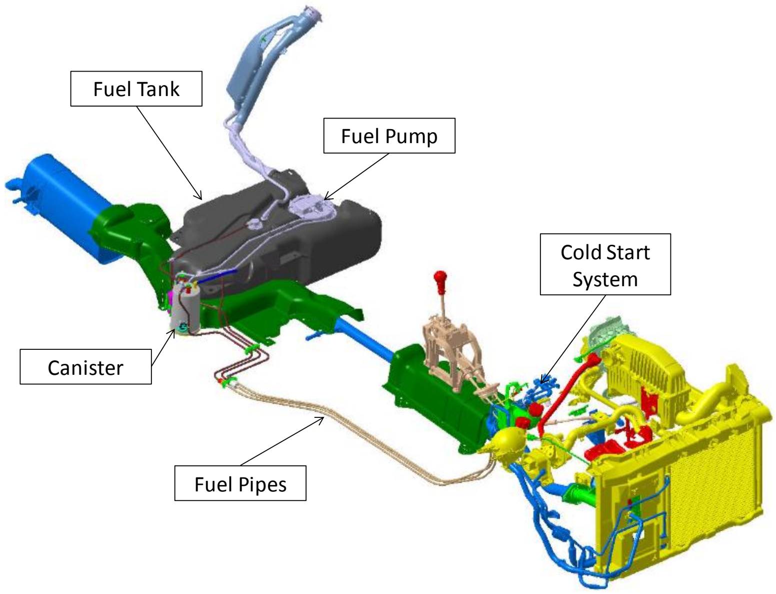

Figure 2. B-segment car: mechanical components highlighting fuel system parts. Source: Authors.

According to Lima, Souza and Camargo (2012) polyamides are interesting because of their mechanical characteristics, atmospheric exposition resistance, low friction coefficient, high melting temperature fatigue resistance, and also excellent resistance to organic solvents. Polyamide 12 (PA-12) is an aliphatic polyamide and some of its physical characteristics are presented in Tab. 1.

Table 1. Polyamide 12 physical characteristics. Source: Lima, Souza and Camargo, 2012.

Physical characteristics	PA-12
Melting Temperature (^oC)	177
Density (g/cm^3)	1.02
Tensile Strenght (Mpa)	52
Flexural Modulus (Mpa)	1,172
Water absorption (%) 24 hs imersion	0.25

According to Bomtempo (2001) polyamides have the major market share among traditional engineering plastics. Only ABS (Acrylonitrile Butadiene Styrene) and PP (Polypropilene) compounds have bigger volume consumption. Its most usual applications are in the automotive industry (32%), electronics (22%) and packaging (14%).

In 2011, the average light vehicle used more than 20 kg of nylon for plastic housings, fuel lines, and brake lines. (Sheffi, 2015). For increasing plastics participation in automobile industry, it would be interesting improve its recyclability, because it's still small compared to other materials, such as steels or aluminum, as showed in Fig. 3.

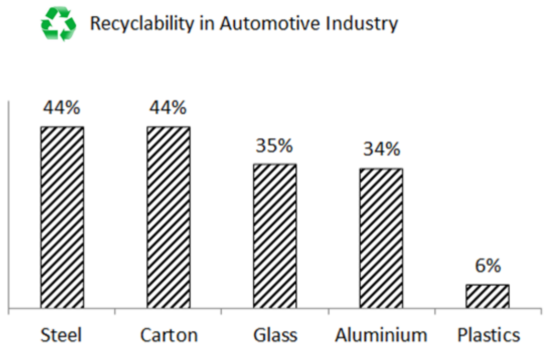

Figure 3. Recyclability percentage of most used materials in automotive industry. Source: Blanchet, 2002.

3. WORLDWIDE CRISES OF PA-12 IN 2012 AND ITS IMPACT FOR THE GLOBAL AUTOMOTIVE INDUSTRY

Recently, for two different reasons, the global suppliers saw difficulties to supply polyamides to all worldwide automakers, especially PA-12. In 2011, the change of petroleum cracking process reduced the raw material availability and some actions have been needed to reduce risk of lack, but problem has been treated without significant impacts.

However, on March 31st, 2012, a tank exploded at Evonik Industries' cyclododecatriene (CDT) plant in Marl, Germany (Sheffi, 2015). According to Yokote (2012), it was not just a local supply cut off, the PA-12 is a specialty produced by only 4 global manufacturers (Evonik, SEM-Chemie Swiss, French Arkema and Japanese Ube) and in this case, Evonik produced at least 25% of world production of PA-12 and worst of all, was responsible for producing 70% of the CDT which is a key ingredient for all PA-12 producers. It is estimated that with this, 50% of world production of PA-12 were threatened.

After the incident, an emergency global action was initialized by the automotive industry to avoid the complete shutdown of Automotive Industry due to the lack of PA-12. According to Eisenstein (2012), Automotive Business (2012) and Carty (2012) about 200 professionals from auto-suppliers and major automaker's executives (including Ford, General Motors, Honda, and others) announced that they had drafted a plan to accelerate the process of testing and approving potential substitutes for PA-12.

According to Lalain (2013), the objective of first meetings were threefold: to help industry understanding and quantifing the current state of global PA-12 inventories and production capacities; to brainstorm options to strategically improve those capacities and/or identify alternative materials or designs to replace PA-12 where it was possible; and to identify and direct the industry resources where required to test and approve such options.

Complicating matters, the PA-12 is used in many functions in vehicles. Some of them easier to replace than others because of the critical level of the application, making it more difficult to find a global and standard solution. Auto parts makers could not easily switch to another chemical quickly because it would need to be thoroughly tested (Lalain, 2013).

The group was not optimistic that the supply of PA-12 could be restarted, and it quickly became evident that the focus should be at the use of alternative raw materials and how to accelerate their approval.

4. STUDY CASE: AUTOMAKER'S REACTION STRATEGIES

4.1. PA-12 uses in studied automaker

This paper has been developed using data from an automaker placed in Rio de Janeiro.

This automaker uses polyamide 12 in its fuel lines in large scale. PA-12 was applied from fuel pumps to cold start systems. So, almost all vehicles produced by this enterprise use this polimer in its fuel lines.

Although the raw material used in the projects for reasons of cost and efficiency compared with other plastics, PA-12 was not essential in some of these applications. And this condition allowed to study the possibility of changing this polymer in not imperative technical uses. The volume of PA-12 suppressed in these applications could be directioned to parts in which imperative properties of PA-12 were required.

The crisis affected several suppliers who bought raw materials from Evonik, impacting producers of different systems and components, such as:

- Fuel tanks suppliers (two in Brazil and Argentine);
- Fuel pumps suppliers (two in Brazil);
- Fuel pipes suppliers (two in Brazil);
- Cold start system supplier (one in Brazil).

As show in the Tab. 2, 87 parts were impacted. To ensure that companies would not be exposed by this article , the names of the suppliers were replaced by codes . Thus, FPI 1 and FPI 2 are the fuel pipes suppliers. FTK 1 and FTK 2 are fuel tank producers. FPP 1 and FPP 2 are suppliers for fuel pumps and FCS 1 is the cold start system supplier.

Table 2. Impacted parts by supplier. Source: Authors.

Systems	Supplier (fictional name)	Impacted parts quantity
Pipes	FPI 1	19
	FPI 2	14
Tank	FTK1	6
	FTK2	33
Pump	FPP1	5
	FPP2	5
Cold start system	FCS1	5
TOTAL		87

Automaker engineering's goal was identifying clearly where this raw material was absolutely unchangeable and adapt all other applications to ensure maximal PA-12 availability for application where it couldn't be replaced.

4.2. The action plan

It was necessary to create a structure to enable quick actions for the integration of various teams and decision-making levels within the automaker and also in suppliers. Identified the initial scenario, it was still necessary creating a "task force" to:

1st - Define and validate in a short time alternative solutions for raw materials, technologies or process;

2nd - Speed up the decision process to ensure SOP (start of production) in much shorter time than in a normal development , without increasing the risk of quality or safety in finished products.

Three working groups in different decision levels (from engineers until directors) were created to treat the situation, any of them with a specific meetings schedule.

<u>Working group 1 – operational level</u>

This working group was composed by two teams. The first one had engineers and buyers from the automaker and engineers and sellers from the suppliers.

This team performed three meetings per week. The leader of these meetings was the automaker's product engineer. The participation of comercial teams from automaker and supplier had the goal of ensure economical availability of technical solutions.

These meetings were called "*Métier Meeting*" and had two goals. The first one was clearly listing all components directly or indirectly impacted by the crisis in consensus with suppliers. The second was to generate proposals for alternative solutions as well as the need for validation and to identify risks involved in possible raw material changes.

Second operational team was composed only by automaker´s engineers.

This group performed two meetings per week, so called "Task Force PA-12", where the leader was the planning engineer. These meetings' goal was check the technical availability and the risks of proposals coming from "*Métier Meeting*".

Working group 2 – managerial level

This working group was composed only by coordinators and managers from the automaker.

During the weekly meeting called " Pre- PEPP " (PEPP is the Portuguese acronym for "Processes and Product Development Meeting") the alternatives , their associated risks and implementation schedule (which also showed PA - 12 estimated Breakpoint for any component) were presented. The goal of this meeting was to prepare and validate the synthesis document to be presented for the Working group 3.

Working group 3 – direction level

Strategic decisions were made by automaker's directors in a weekly meeting called PEPP. This forum used as input information the synthesis document from *Pré-PEPP*.

The main goal of this meeting was define which solutions would be adopted. After this, the team started to check the solutions application, one by one.

Decision Level	Monday	Tuesday	Wednesday	Thursday	Friday
Managerial				PEPP	
Coordination			Pré-PEPP		
Operational (Timing)		Task Force		Task Force	
Operational (Technical)	Metier Meeting		Metier Meeting		Metier Meeting

Figure 4. PA-12 crisis meetings: week schedule. Source: Authors.

This structure has been active from April till December 2012 and allowed treating all cases impacted by PA-12 crisis.

5. RESULTS

The final results achieved by the working group are shown in Tab. 3. Out of a total of 87 part numbers directly impacted by the shortage crisis of PA-12, only 34 (approximately 40% of total parts) could be replaced by alternative raw materials. The use of PA12 was essential for all other 53 parts.

Table 3 – Impacted parts by shortage of PA-12. Source: Authors.

Systems	Supplier (fictional name)	Impacted parts quantity	
		First analysis (April/12)	Possible to change raw material (after analysis of the working group)
Pipes	FPI 1	19	2
	FPI 2	14	14
Tank	FTK1	6	3
	FTK2	33	5
Pomp	FPP1	5	5
	FPP2	5	5
Cold start system	FCS1	5	0
TOTAL		87	34

To achieve these results, the working group held several complex tasks for more than nine months of 2012. Not only the complexity, but also the diversity of activities, have required extensive team work to analyze the situation and decide preventive actions. It is highlighted below the activities which most contributed to minimize the consequences of PA-12 shortage:

1. Participation of suppliers from Brazil and Argentine (Tiers 1 and Tiers 2). Suppliers commitment was critical to search for raw materials alternative;
2. Exhaustive tests and trials were carried out by Engineering Department;
3. Strong control and validation processes assured by Quality Management Team;
4. Quick Quick approval, draw and documentation updates for modified parts;
5. New commercial prices for updated parts;
6. Efficient Implementation of logistics processes for alternative raw material and new part numbers.

6. FINAL CONSIDERATIONS AND CONCLUSIONS

6.1. Analyzed automaker’s perspective

From the analysed automaker's perspective, the proactive management of crisis described in this study has ensured the normal production of vehicles during the year of 2012. The team's work has allowed right decisions to implement the necessary changes to production. Changes were conducted based on commitment of directors and operational teams which avoided disruption to the assembly lines.

The working group also contributed for starting discussions on the usage of an alternative “green” raw material which could partially replace PA-12 in the design and the development of fuel pipes in the near future. It is a significant step to reach larger participation of recyclable raw materials in the composition of automotive parts.

6.2 Global automotive industry perspective

From the global automotive industry perspective, the Evonik disaster at 2012 is simply a chapter more in the history of supply chain disruptions. One year before, the tsunami in Japan resulted in destruction of many auto suppliers plants. Thus, the incident of Evonik renforces the fragility in the world’s supply chain.

The crisis raises an important question: how is it possible for one supplier to impact so many different automakers? A single-sourcing strategy can reduce costs and improve quality, but it also lets a company exposed to serious disruptions if a key supplier faces a crisis. The most reasonable long term solution seems to be the development of many raw material sources, by diversifying suppliers. Although diversification minimizes risks, the study indicates that only the design and development of auto parts using alternative materials could ensure stability for the automotive processes.

The strategies the automotive industry handled the PA-12 crisis created a new path for how to accelerate the approval process for alternate materials that could be used in different situations in the future.

The issue of PA-12 prompted many discussions and concerns about risks of shortage of others raw materials currently employed in a broad scale by auto parts companies, such as heavy metals found in batteries (also in electrical vehicles) and components for electronic assemblies. Long term solutions to avoid the shortage should be investigated and deployed in the automotive industry. The rupture of PA-12 supply showed that curative measures are feasible; however it demands excessive resources to manage and monitor constant risks of production shutdown.

Therefore, preventive measures should be stimulated and supported along supply chain of automotive industry. Brainstorming, teamwork, project management are excellent tools to encourage ideas and to turn them into implementation actions before a shortage crisis. As consequence, proactive work can reduce risks and costs for the entire chain of automobile producers. Concerning this approach, a positive point to highlight of this disaster is that the automakers were willing to work collaboratively to solve the problem. Possibly that could be extended to other areas, such as sharing certification data for tests, for example.

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